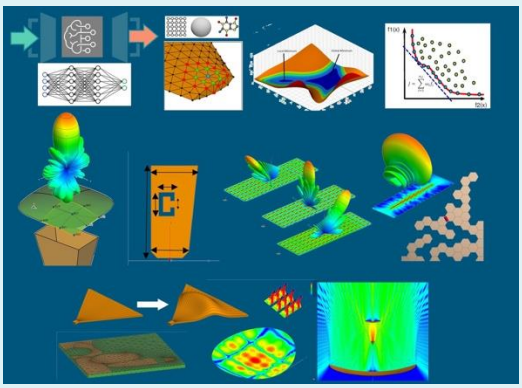
SC02 - Antenna Design using Optimization and Machine Learning



Abstract:

Traditional antenna optimization solves the modified version of the original antenna design for each iteration. Thus, the total time required to optimize a given antenna design is highly dependent on the convergence criteria of the selected algorithm and the time taken for each iteration. Machine Learning (ML) is a method of data analysis that automates analytical model building. As the antennas are becoming more and more complex each day, antenna designers can take advantage of machine learning to generate trained models for their physical antenna designs and perform fast and intelligent optimization on these trained models.

The short course covers many aspects such as data generation, validation of prediction models and integration in an optimization workflow. ML methods of different complexity are presented and typical challenges for different types of antenna optimization, like size optimization, shape optimization, topology optimization and generative design are illustrated by examples.

Recommended pre-requisites:

This tutorial is intended for antenna designers who would like to learn basics of machine learning methods and their application to antenna design optimization, but also other RF applications such as radar cross section (RCS) predictions. Experience with electromagnetic simulation tools (commercial or otherwise) will help, but not required to attend the tutorial.

Learning Objectives:

After the tutorial, participants will be able to understand differences between various machine learning (ML) techniques and can apply them to real live antenna optimization problems. This knowledge will help them choose suitable ML algorithms to create AI models for fast predictions. Participants will also learn about the advantages and disadvantages of different optimization methods and will understand workflows for different types of RF optimization problems.

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Course Outline:

Course Outline for “Antenna Design using Optimization and Machine Learning”

- What is Machine Learning?
  - Data Generation and Validation of Prediction Models
  - Supervised Learning: From linear Regression to Geometric Deep Learning
  - Other Methods: Cluster Analysis, Decision Trees and Ensemble Learning
  - Evolutionary Learning
- Antenna Optimization
  - Overview of Optimization Methods
  - Strategies to include Machine Learning into Optimization
  - Multi-Objective Optimization and Pareto-optimal Designs
  - Size Optimization and Shape Optimization
  - Topology Optimization and Generative Design
- Examples and Workflows
  - Several Antenna Examples to demo parametrized Simulation models, Design of Experiments, Training of ML Models and Optimization

Note: Participants need not bring a laptop.

Instructors:

Dr. Christoph Mäurer is Lead Technical Specialist EM Solutions at Altair Engineering, that is now part of Siemens Digital Industries.

He received his M.S. (Diplom) in 1994 and his PhD in 1997 from TU Darmstadt. He has been working in the area of computational electromagnetics for over 25 years in different roles. This includes many customer projects for antenna optimization, antenna integration and EMC in automotive, aero, space and telecommunication. He is particularly interested in how new methods can be integrated into simulation and optimization processes to make them more efficient. Since 2022 he worked on development projects to improve simulation methods in Altair Feko. He is also interested in the use of supervised learning methods in Computational Electromagnetics. He published several papers about CAGD, CEM, Optimization and ML.

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Dr. C.J. Reddy is the Vice President, Business Development-Electromagnetics for Americas at Altair. Dr. Reddy was a research fellow at the Natural Sciences and Engineering Research Council (NSERC) of Canada and was awarded the US National Research Council (NRC) Resident Research Associateship at NASA Langley Research Center. While conducting research at NASA Langley, he developed various computational codes for electromagnetics and received a Certificate of Recognition from NASA for development of a hybrid Finite Element Method/Method of Moments/Geometrical Theory of Diffraction code for cavity backed aperture antenna analysis. Dr. Reddy is a Fellow of IEEE, Fellow of ACES (Applied Computational Electromagnetics Society) and a Fellow of AMTA (Antenna Measurement Techniques Association). Dr. Reddy is a co-author of the book, “Antenna Analysis and Design Using FEKO Electromagnetic Simulation Software,” published in June 2014 by SciTech Publishing (now part of IET). Dr. Reddy is elected as the President-Elect of the IEEE Antennas and Propagation Society (AP-S) and will serve as the President of IEEE AP-S in 2026.

Key Bibliography:

1. C. Maeurer, P. Futter and G. Gampala, "Antenna Design Exploration and Optimization using Machine Learning," 2020 14th European Conference on Antennas and Propagation (EuCAP), Copenhagen, Denmark, 2020.

2. C. Mäurer, A. Mudgal and A. Raja, "RCS Predictions Using Geometric Deep Learning," 2025 19th European Conference on Antennas and Propagation (EuCAP), Stockholm, Sweden, 2025.

3. G. Gampala and C. J. Reddy, "Fast and Intelligent Antenna Design Optimization using Machine Learning," 2020 International Applied Computational Electromagnetics Society Symposium (ACES), Monterey, CA, USA, 2020.